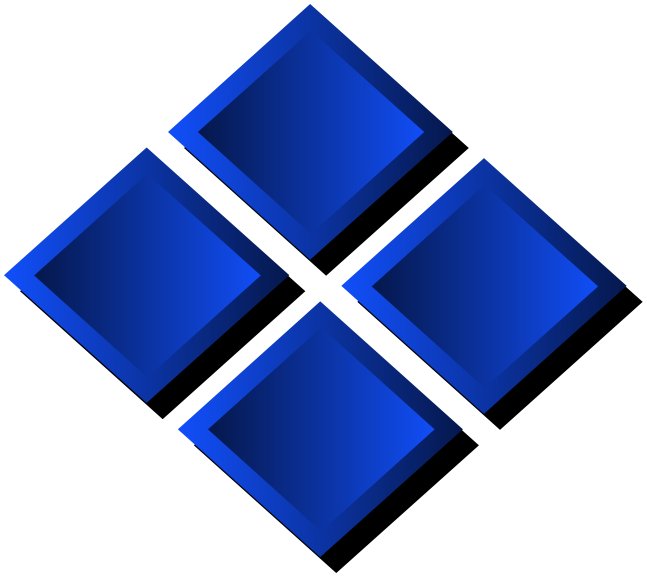

Strategies for Applying the CMMI® to Software Maintenance

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Agenda

- The Five Types of Software Maintenance
- Maintenance in the System Life Cycle
- Maintenance in the Software Life Cycle
- The CMMI® and Maintenance
- Maintenance-Related CMMI® Process Areas
- Issues for Software Maintenance Organizations
  - Estimation for Maintenance
  - Maturity Level Determination

Five Types of Software Maintenance

- Corrective Maintenance
  - Identify and remove defects
  - Correct actual errors

- Perfective Maintenance
  - Improve performance, dependability, maintainability
  - Add new functionality

- Adaptive Maintenance
  - Adapt to a new/upgraded environment (e.g., hardware, operating system, middleware)

- Preventive Maintenance
  - Identify and detect latent faults
  - Systems with safety concerns

- Emergency Maintenance
  - Unscheduled corrective maintenance

  (Risks due to reduced testing)

Two Types of Maintenance Activities – Bug Fixing

- Corrective Maintenance
  - Identify and remove defects
  - Correct actual errors

- Preventive Maintenance
  - Identify and detect latent faults
  - Systems with safety concerns

- Emergency Maintenance
  - Unscheduled corrective maintenance

(Risks due to reduced testing)

Two Types of Maintenance Activities – Development/Migration

Post-Delivery

- Perfective Maintenance
  - Improve performance, dependability, maintainability
  - Add new functionality

- Adaptive Maintenance
  - Adapt to a new/upgraded environment (e.g., hardware, operating system, middleware)

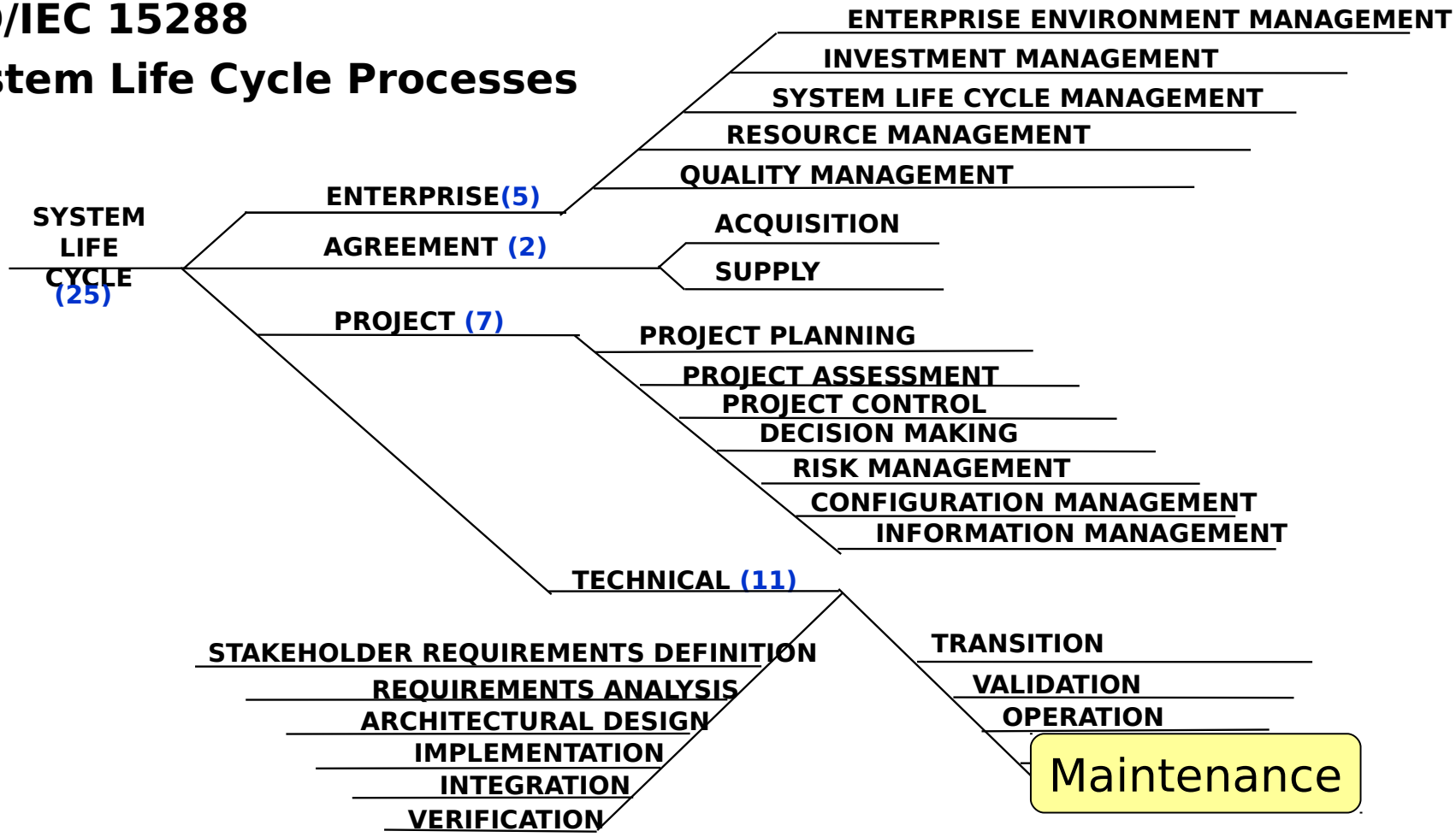
Development/Migration

How do we know what the objectives and expected outcomes should be for Maintenance?

Maintenance in the System Life Cycle

ISO/IEC 15288

System Life Cycle Processes



ISO/IEC 15288 – Maintenance Process – Purpose

- Clause 5.5.11.1 Purpose of the Maintenance Process
  - The purpose of the Maintenance Process is to ***sustain the capability of the system to provide a service.***
  - This process ***monitors*** the system's capability to deliver services, ***records problems*** for analysis, ***takes corrective, adaptive, perfective and preventive actions*** and ***confirms restored capability***.

Source: ISO/IEC 15288:2002, © ISO/IEC2002.

ISO/IEC 15288 – Maintenance Process – Expected Outcomes

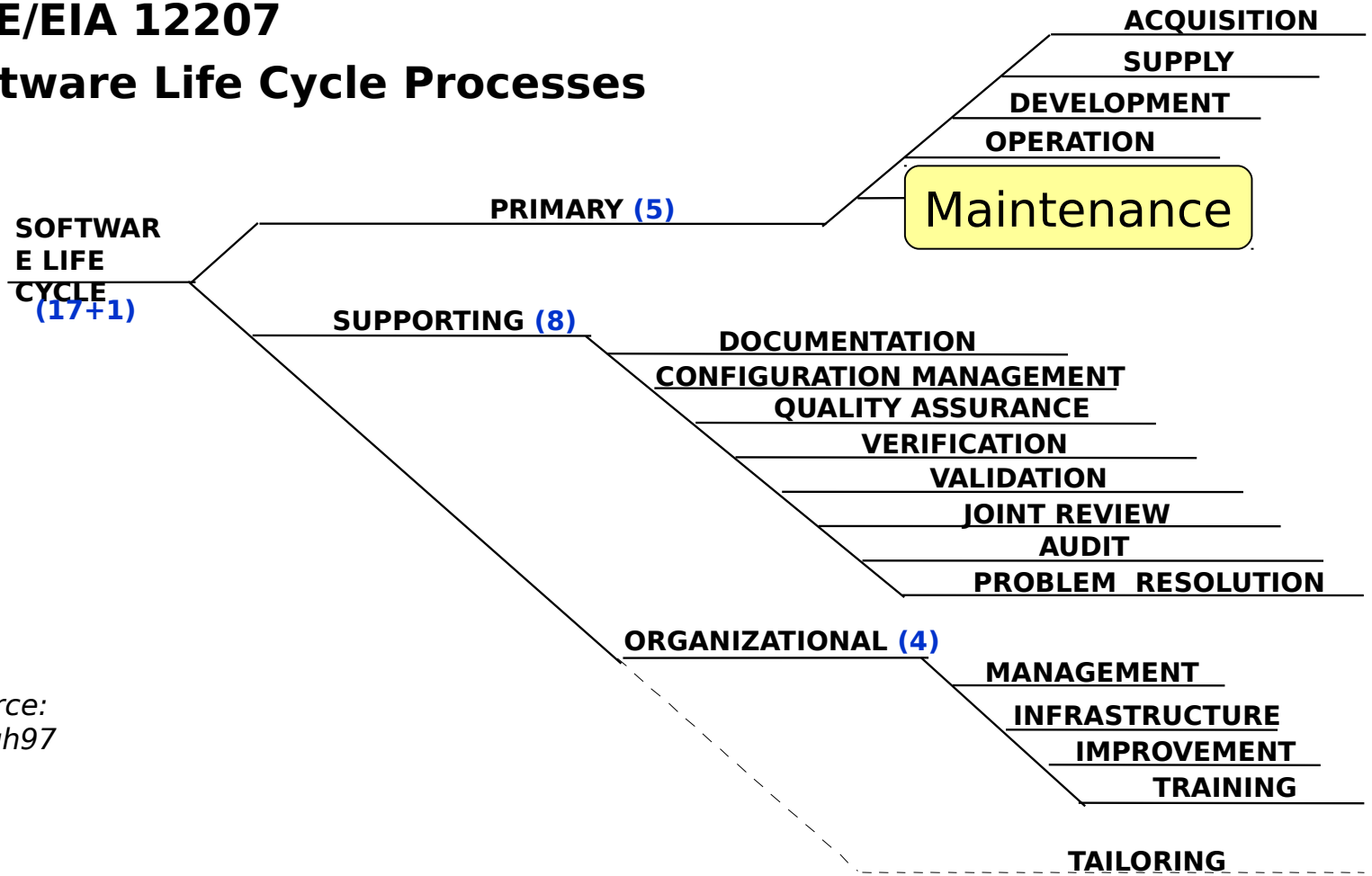
- Clause 5.5.11.2 Maintenance Process Outcomes
  - As a result of the successful implementation of the Maintenance Process:
  - a) A ***maintenance strategy*** is developed.
  - b) ***Maintenance constraints*** are provided as inputs to requirements.
  - c) ***Replacement system elements*** are made available.
  - d) ***Services*** meeting stakeholder requirements ***are sustained***.
  - e) The ***need for corrective design changes is reported***.
  - f) ***Failure and lifetime data is recorded***.

Source: ISO/IEC 15288:2002, © ISO/IEC2002.

Maintenance in the Software Life Cycle

IEEE/EIA 12207

Software Life Cycle Processes



Source: Singh97

IEEE/EIA 12207 – Maintenance Process – Purpose

- Clause 5.5 Maintenance process
  - This process is activated when the software product undergoes ***modifications*** to code and associated documentation ***due to a problem or the need for improvement or adaptation***
    - ***The objective is to modify the existing software product while preserving its integrity***
    - This process includes the migration and retirement of the software product
    - The process ends with the retirement of the software product
  - The activities provided in this clause are specific to the Maintenance Process; however, the process may utilize other processes in this International Standard. If the Development Process (5.3) is utilized, the term developer there is interpreted as maintainer

Source: IEEE/EIA 12207.0-1996, © IEEE.1998

IEEE/EIA 12207 – Maintenance Process – Expected Outcomes

- Appendix G, Clause G.9 Maintenance process
  - The use of the Maintenance process should achieve the following objectives:
    - a) ***Define*** the ***impact*** of organization, operations, and interfaces ***on the existing system in operation***;
    - b) ***Identify and update*** appropriate life cycle ***data***;
    - c) ***Develop modified system components*** with associated documentation ***and tests*** that ***demonstrate that the system requirements are not compromised***;
    - d) ***Migrate system and software upgrades*** to the user's environment;
    - e) ***Ensure fielding*** of new systems or versions ***does not adversely affect ongoing operations***;
    - f) ***Maintain the capability to resume*** processing ***with prior versions***.

Source: IEEE/EIA 12207.0-1996, © IEEE.1998

How does the CMMI® Treat Maintenance?

- Development
  - The word “development,” when used in the CMMI Product Suite, implies not only development activities, but also ***maintenance*** activities.
  - Projects that benefit from the best practices of CMMI can focus on ***maintenance***, development, or both.

Source: CMMI® -SE/SW/IPPD/SS, V1.1, Continuous Representation, © CMU SEI,2002.

The term *Maintenance* appears in the CMMI 70 times

How does the CMMI® map to the consensus-based objectives and expected outcomes for Maintenance?

The CMMI® and System Maintenance – Objectives

ISO/IEC 15288 Maintenance Objectives	CMMI® Process Areas
Monitor the system's capability to deliver services	PMC, PPQA, RSKM
Record problems for analysis	VER, VAL, CM, CAR, PPQA, RSKM
Take corrective, adaptive, perfective and preventive actions	CM, CAR, RD, REQM, TS, PI, RSKM
Confirm restored capability	VER, VAL, PMC

The CMMI® and System Maintenance –

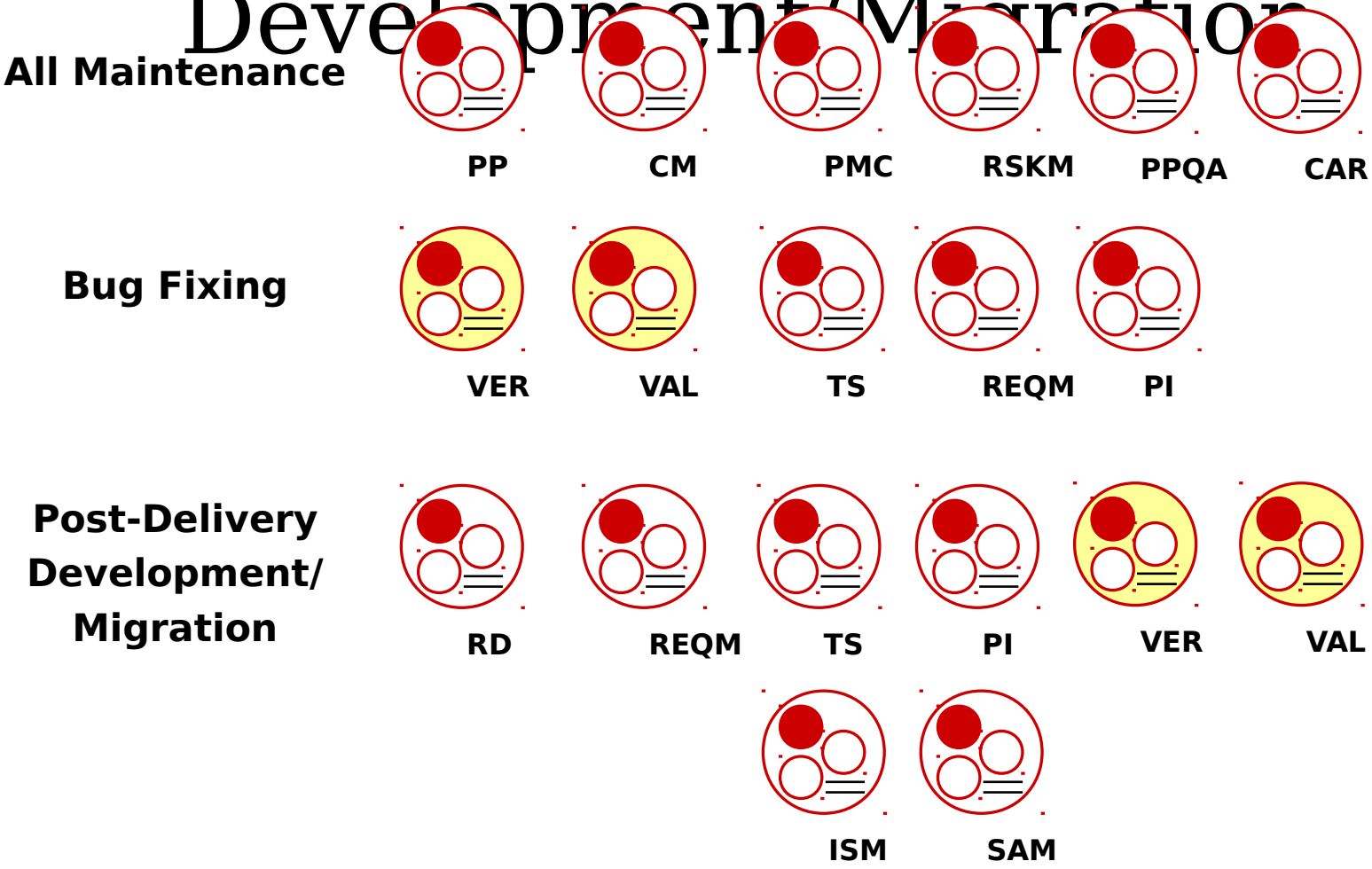
ISO/IEC 15288 Maintenance Outcomes	CMMI® Process Areas
A ***maintenance strategy*** is developed	PP, TS
Maintenance constraints are provided as inputs to requirements	RD, PI
Replacement system elements are made available	PMC, SAM, ISM
Services meeting stakeholder requirements ***are sustained***	PPQA, RSKM, RD, CM
The ***need for corrective design changes is reported***	PPQA, CM, RSKM, PMC
Failure and lifetime data is	

The CMMI® and Software Maintenance –

IEEE/EIA 12207 Maintenance Objectives	CMMI® Process Areas
Define the ***impact*** of organization, operations, and interfaces ***on the existing system in operation***	TS, RSKM
Identify and update life cycle ***data***	RD, REQM, RSKM
Develop modified system components with associated ***documentation and tests*** that ***demonstrate that the system requirements are not compromised***	TS, PI, VER, VAL, CM, PPQA, RSKM
Migrate system and software upgrades to the user's environment	PI, CM, PPQA
Ensure fielding of new systems or versions ***does not adversely affect ongoing operations***	VER, VAL, RSKM
Maintain the capability to resume processing ***with prior versions***	TS, CM

Let’s take a closer look at several places where Maintenance-related activities occur in the CMMI®

Bug Fixing vs. Post-Delivery Development/Migration

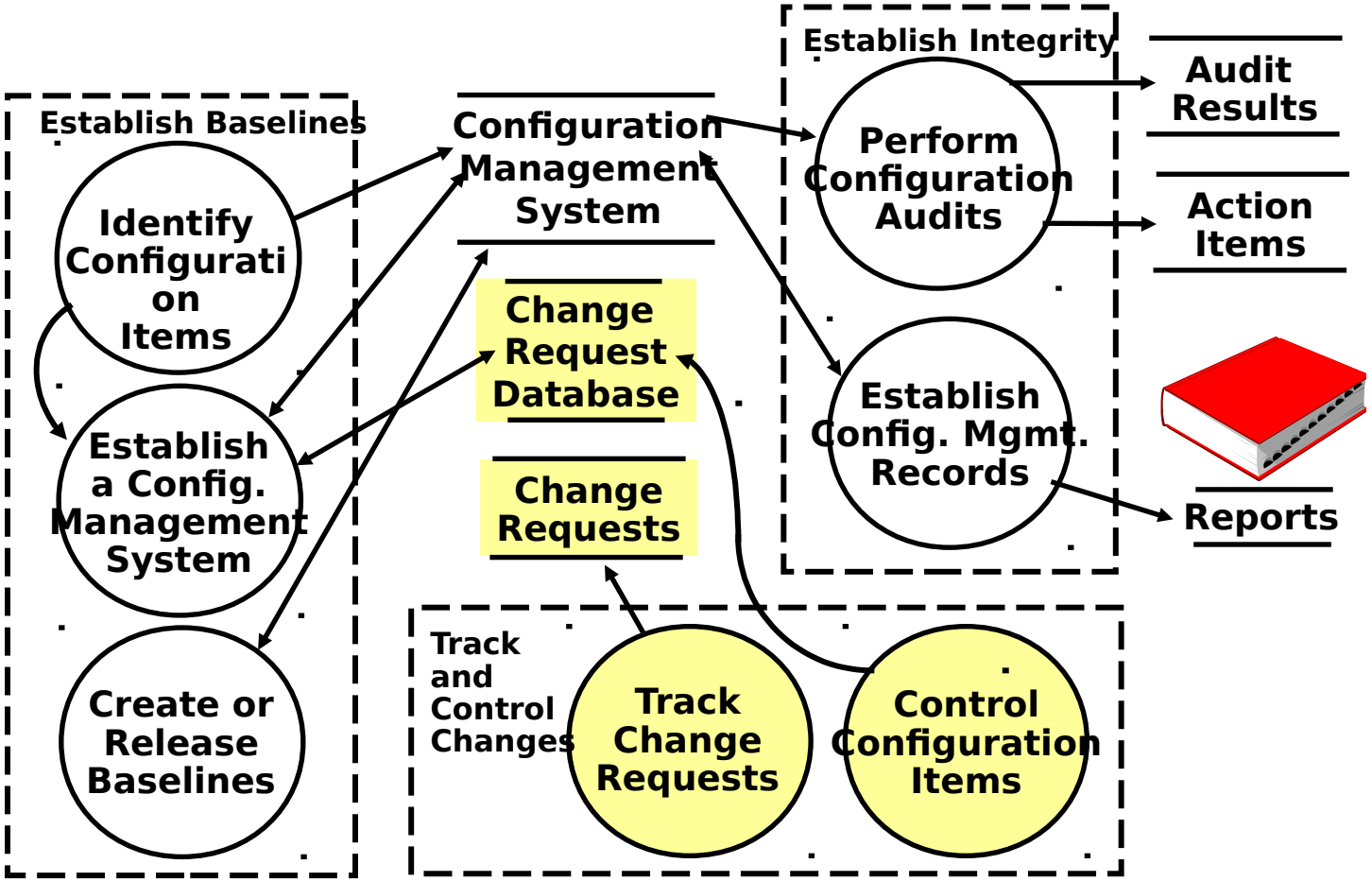


Configuration Management

- Changes to baselines and the release of work products built from the configuration management system are systematically controlled and monitored via the configuration control, ***change management***, and configuration auditing functions of configuration management.
  - Refer to the ***Causal Analysis and Resolution*** process area for more information about both the method to use for ***analyzing the impact of change requests and the method to use when evaluating changes***
  - Refer to the ***Project Monitoring and Control*** process area for more information about performance analyses and ***corrective actions***

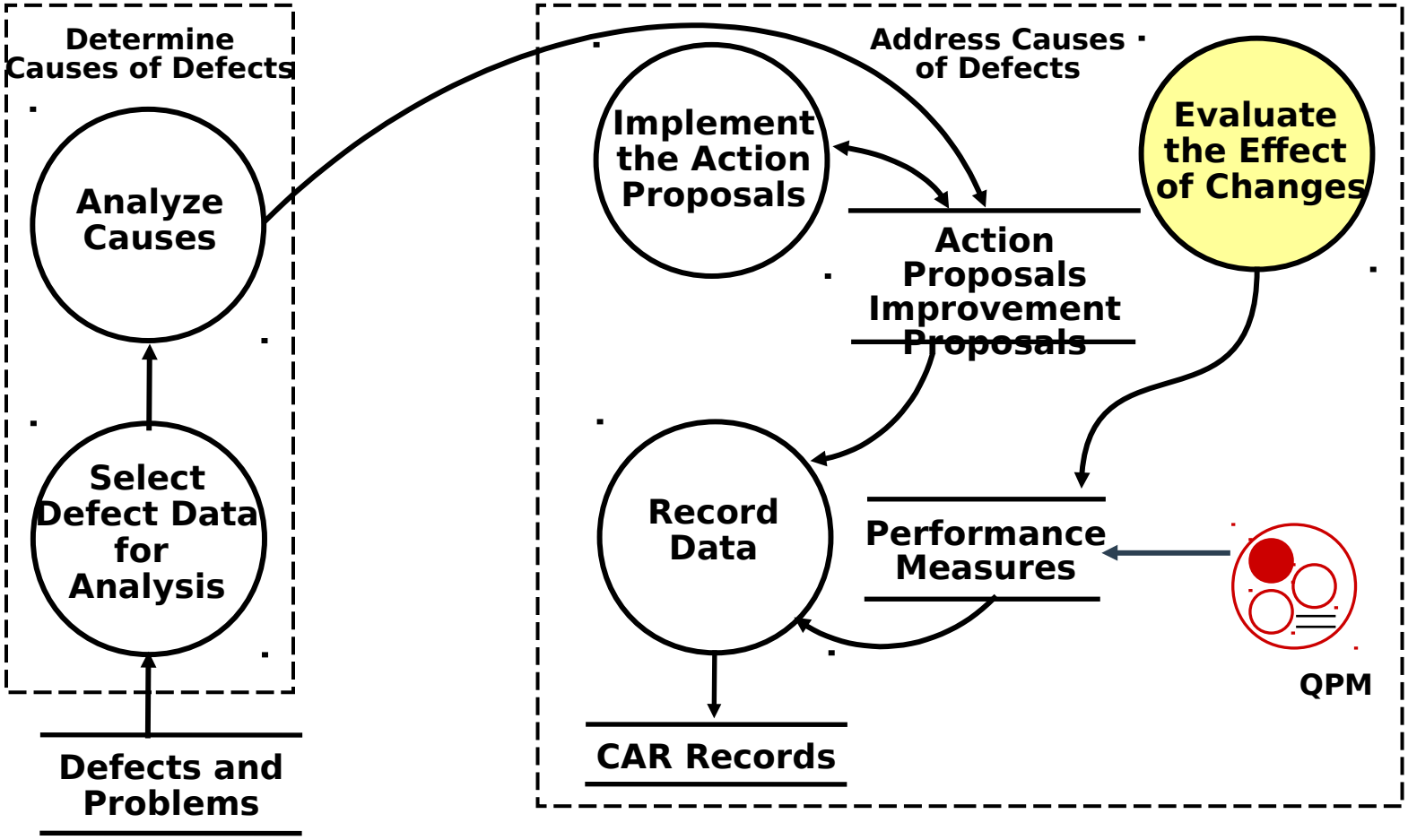
Source: CMMI® -SE/SW/IPPD/SS, V1.1, Continuous Representation, © CMU SEI,2002

CM – Tracking and Controlling Changes



Source: Introduction to CMMI-Continuous V 1.1 © 2002-2003 by Carnegie Mellon University

CAR – Evaluating the Effect of Changes



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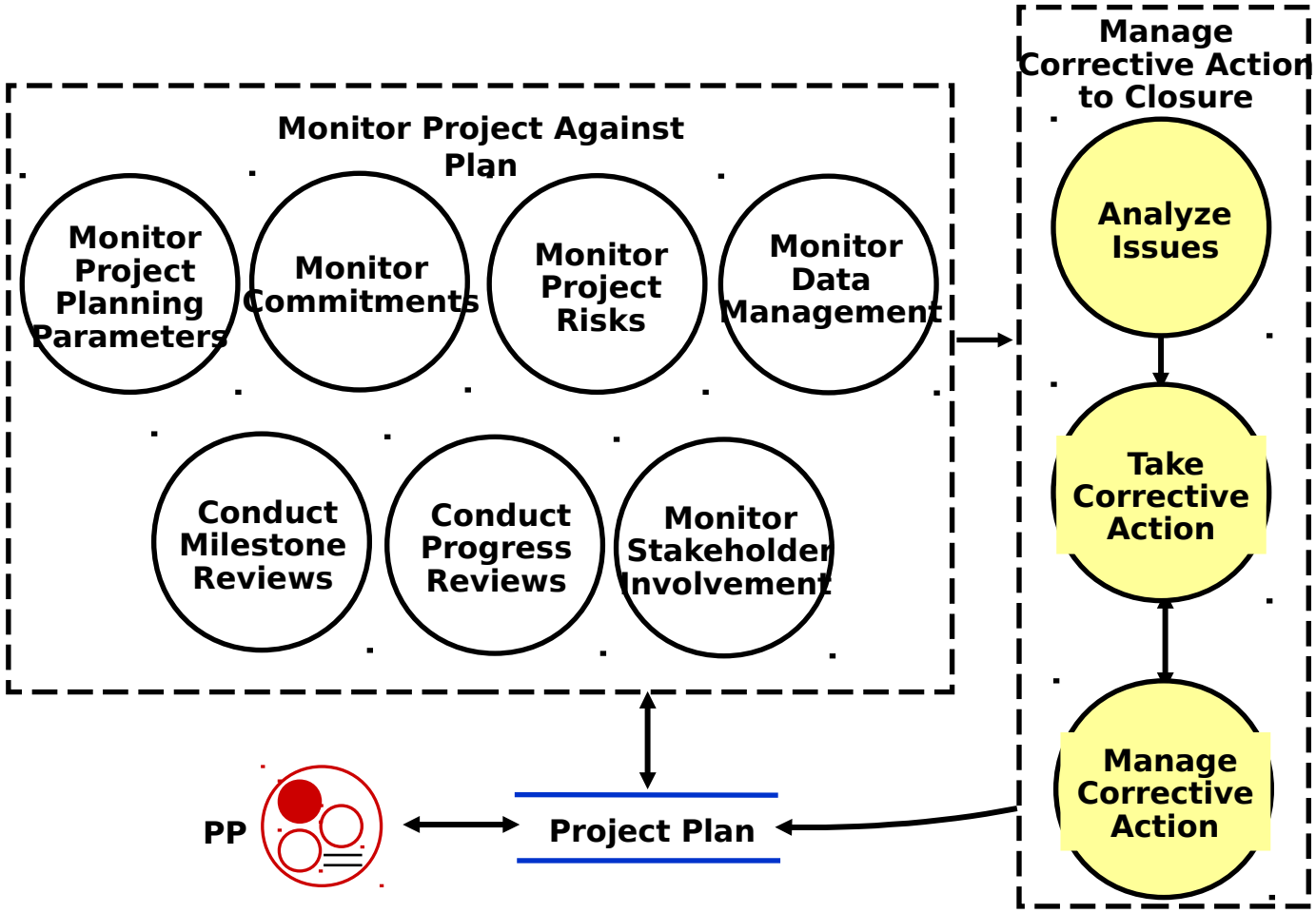
PMC – Managing Corrective Actions



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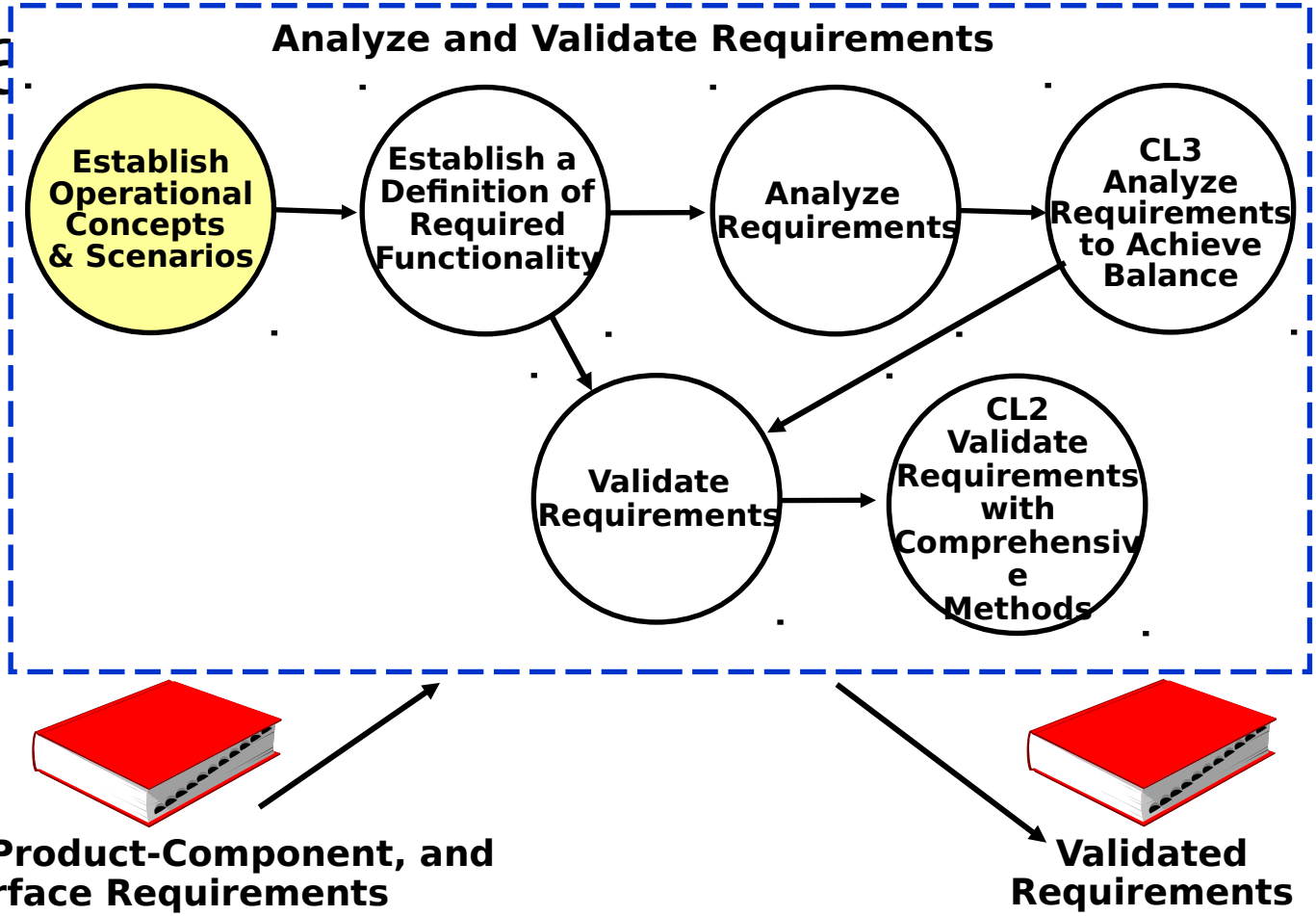
Requirements Development

- SP 3.1-1Establish Operational Concepts and Scenarios
  - *Establish and maintain operational concepts and associated scenarios.*
    - Subpractices
      - 1. Develop operational concepts and scenarios that include functionality, performance, ***maintenance***, support, and disposal as appropriate.

Source: CMMI® -SE/SW/IPPD/SS, V1.1, Continuous Representation, © CMU SEI,2002

RD – Establishing Operational Concepts a


Analyze and Validate Requirements
Establish Operational Concepts & Scenarios
Establish a Definition of Required Functionality
Analyze Requirements
CL3 Analyze Requirements to Achieve Balance
Validate Requirements
CL2 Validate Requirements with Comprehensive Methods
Product, Product-Component, and Interface Requirements
Validated Requirements

Source: Introduction to CMMI-Continuous V 1.1 © 2002-2003 by Carnegie Mellon University

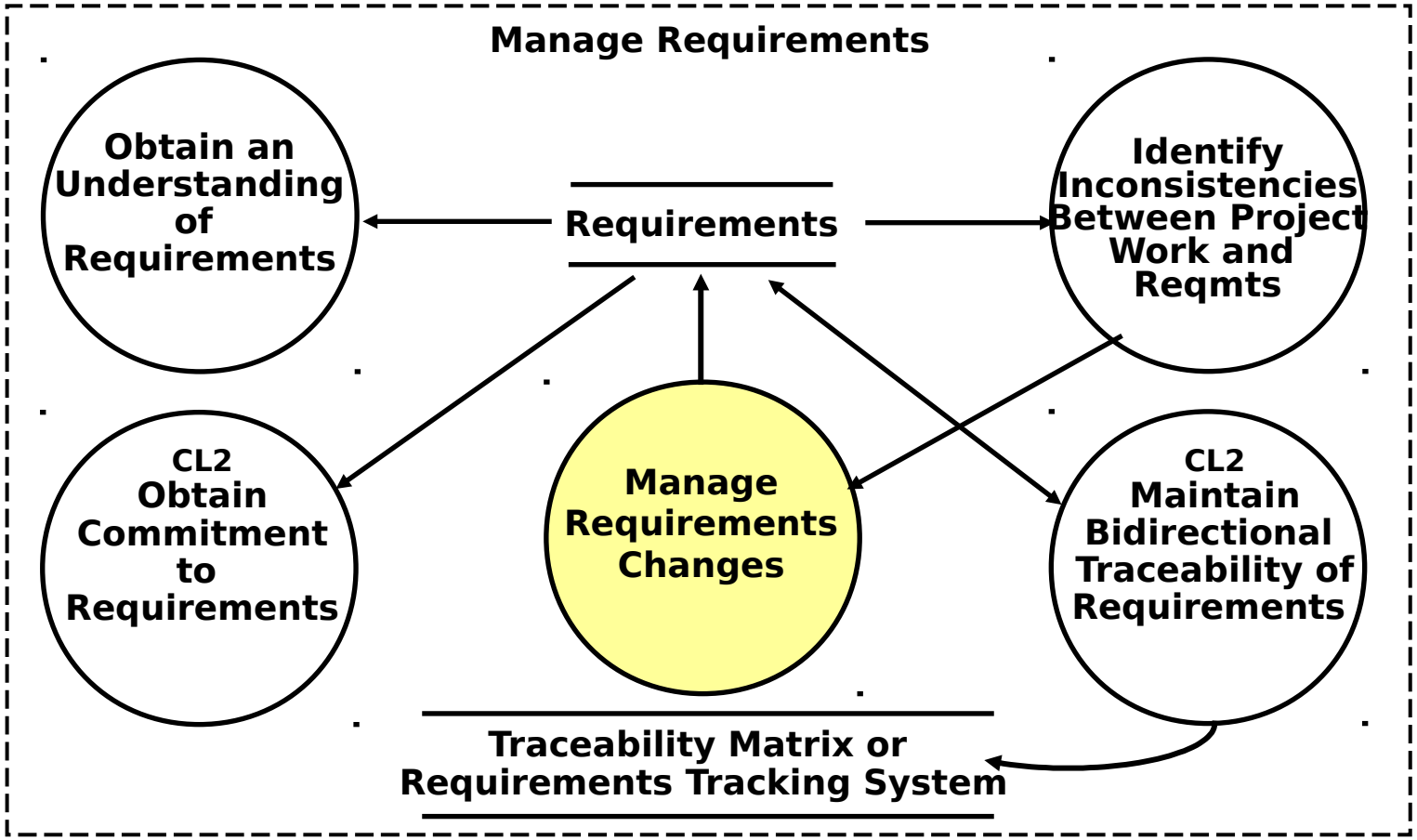
Requirements Management

Part of the management of requirements is to document requirements changes and rationale and maintain bi-directional traceability between source requirements and all product and product-component requirements.

- SP 1.3-1Manage Requirements Changes
  - *Manage **changes** to the requirements as they evolve during the project.*

Source: CMMI® -SE/SW/IPPD/SS, V1.1, Continuous Representation, © CMU SEI,2002

REQM – Managing Requirements Changes


Manage Requirements
Obtain an Understanding of Requirements
Requirements
Identify Inconsistencies Between Project Work and Reqmts
CL2 Obtain Commitment to Requirements
Manage Requirements Changes
CL2 Maintain Bidirectional Traceability of Requirements
Traceability Matrix or Requirements Tracking System

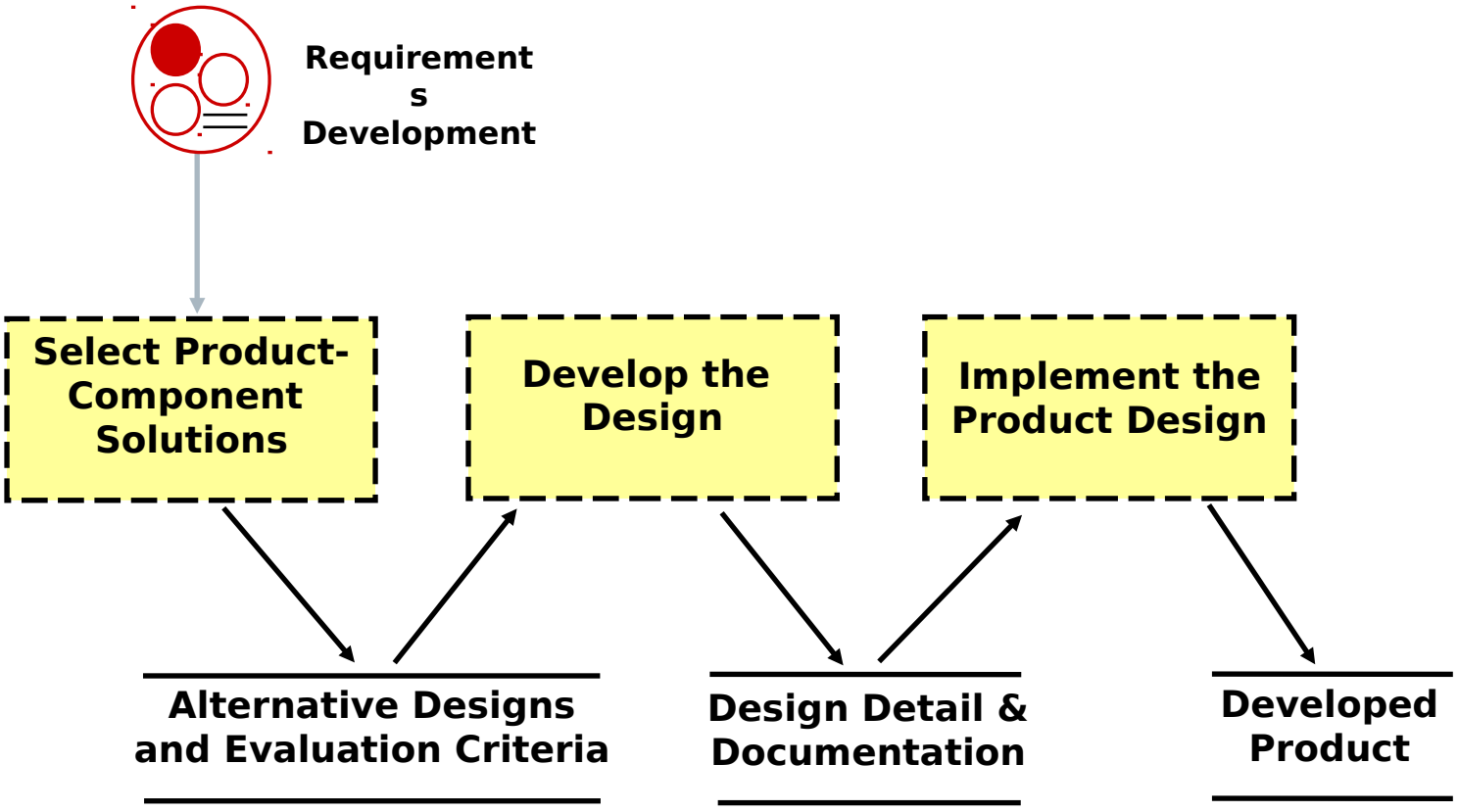
Source: Introduction to CMMI-Continuous V 1.1 © 2002-2003 by Carnegie Mellon University

Technical Solution

- For a ***maintenance or sustainment organization***, the requirements in need of ***maintenance actions*** or ***redesign*** may be driven by ***user needs or latent defects*** in the product components. ***New requirements may arise from changes in the operating environment.*** Such requirements can be uncovered during verification of the product(s) where actual performance can be compared against the specified performance and unacceptable degradation can be identified. ***Processes associated with the Technical Solution process area should be used to perform the maintenance or sustainment design efforts***.

Source: CMMI® -SE/SW/IPPD/SS, V1.1, Continuous Representation, © CMU SEI,2002

TS – Maintenance Design Efforts



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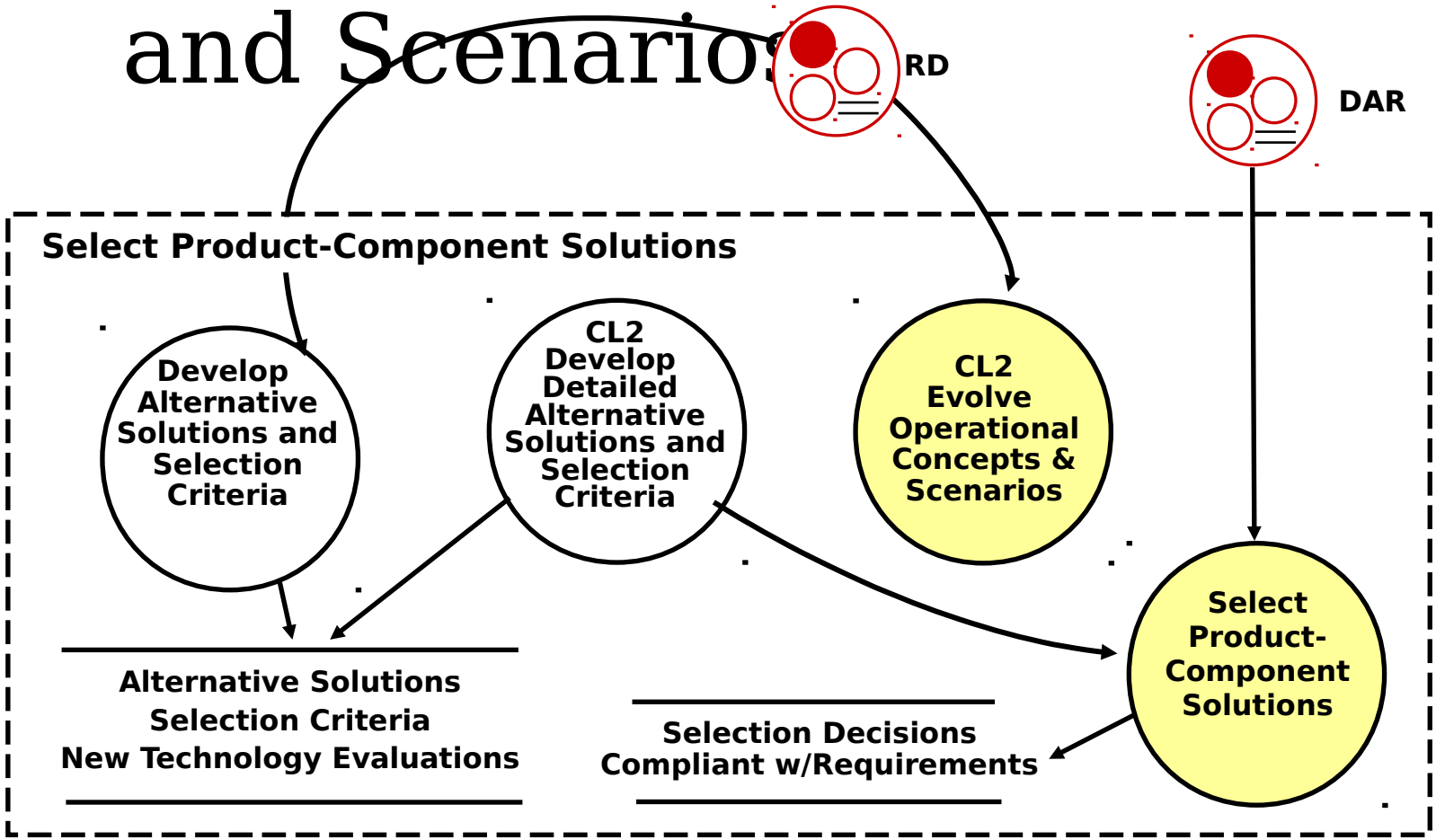
TS – Evolving Operational Concepts and Scenarios



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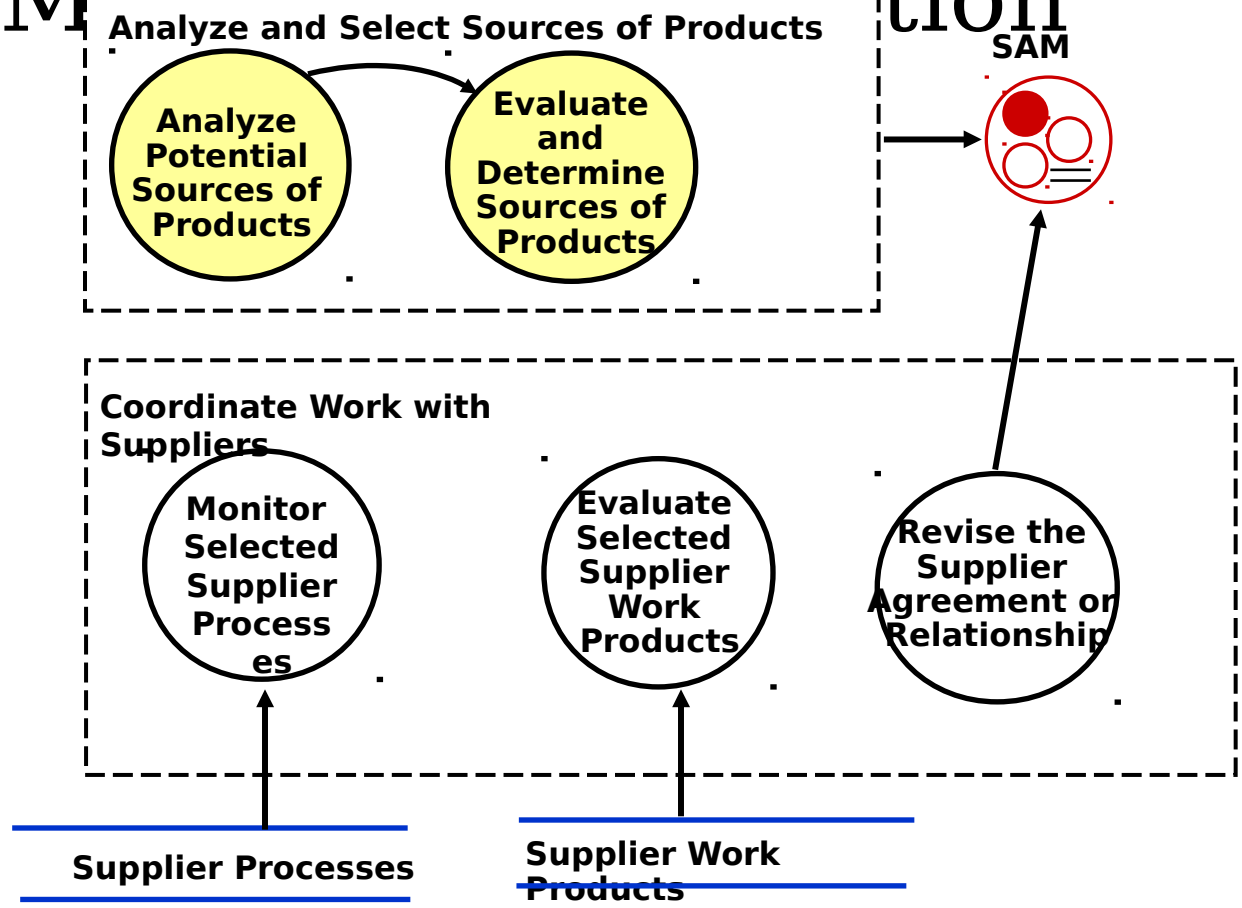
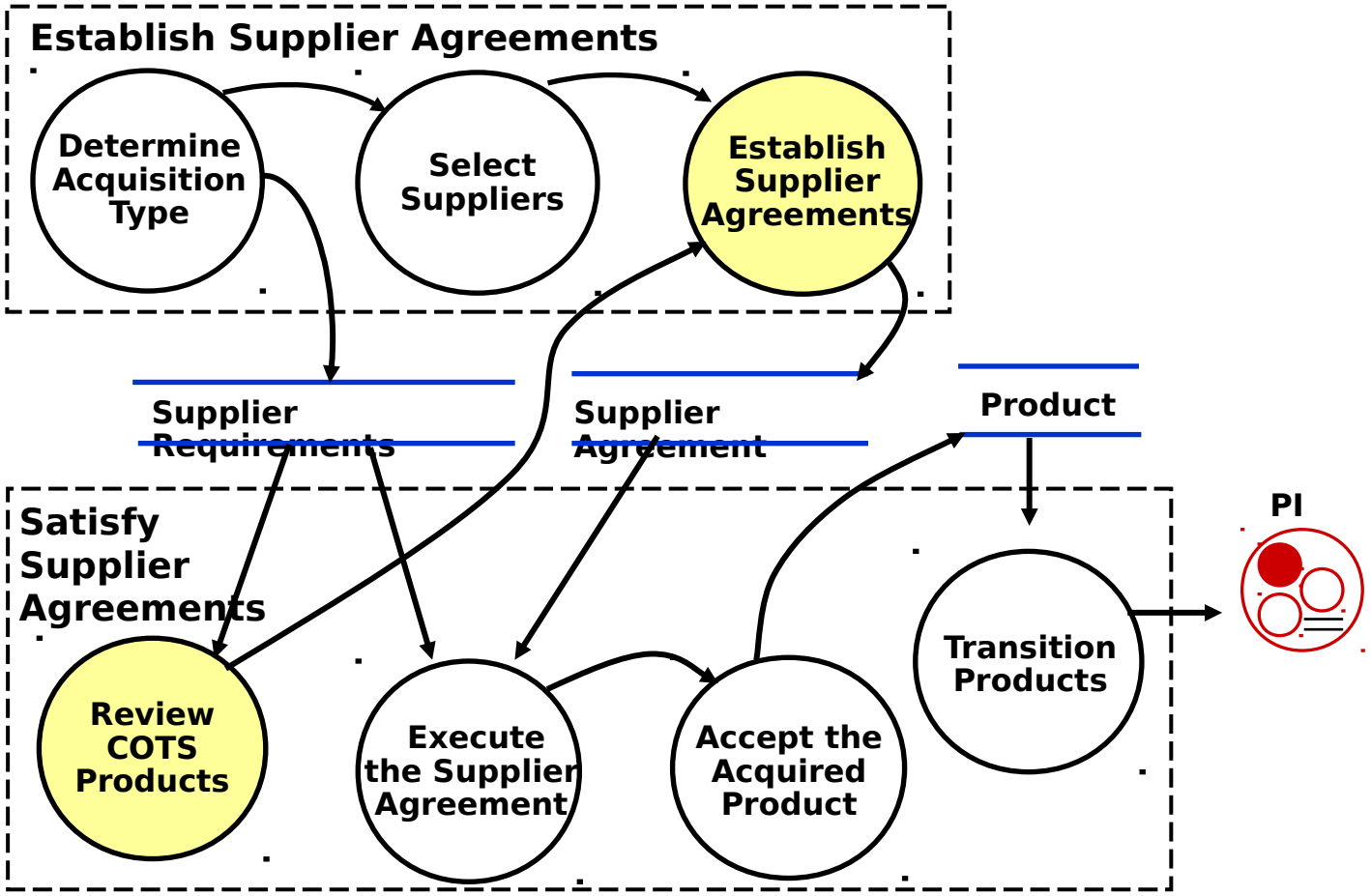
ISM – Sourcing When COTS is a Part of the Maintenance Solution


Analyze and Select Sources of Products
Analyze Potential Sources of Products
Evaluate and Determine Sources of Products
SAM
Coordinate Work with Suppliers
Monitor Selected Supplier Process es
Evaluate Selected Supplier Work Products
Revise the Supplier Agreement or Relationship
Supplier Processes
Supplier Work Products

Source: Introduction to CMMI-Continuous V 1.1 © 2002-2003 by Carnegie Mellon University

SAM – Managing the COTS Supplier



Source: Introduction to CMMI-Continuous V 1.1 © 2002-2003 by Carnegie Mellon University

COTS Integration is Not Trivial

- Effective COTS integration requires:
  - Good market research
  - In-depth vendor discussions
  - Candidate product verification
  - Diminishing manufacturing sources risk mitigation planning
  - Efficient product selection* and procurement
  - Middleware development and integration

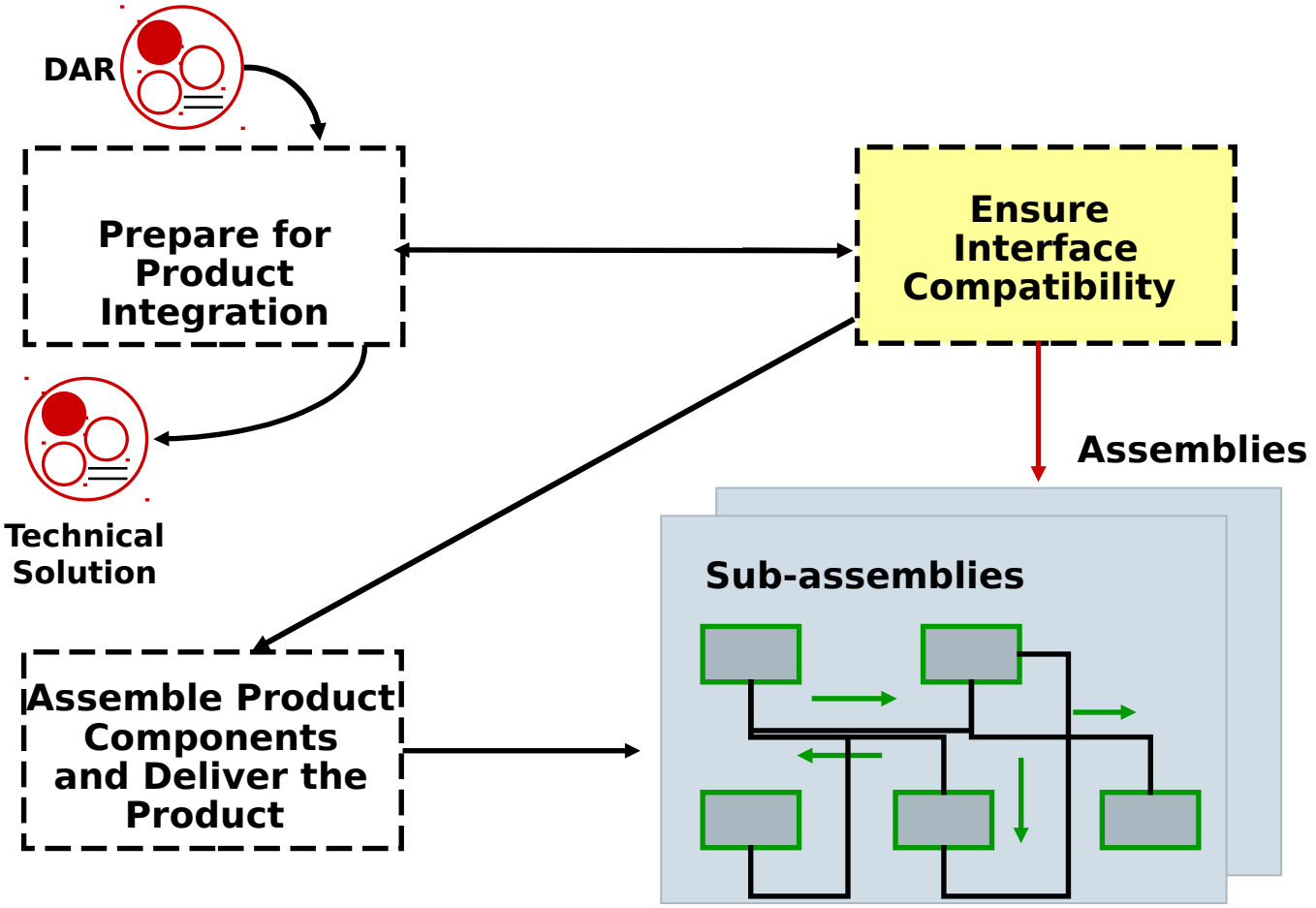
***Use DAR**

Product Integration

- SP 2.2-1 Manage Interfaces
  - Manage internal and external interface definitions, designs, and changes for products and product components.
    - Management of the interfaces includes ***maintenance of the consistency of the interfaces throughout the life of the product, and resolution of conflict, noncompliance, and change issues***.

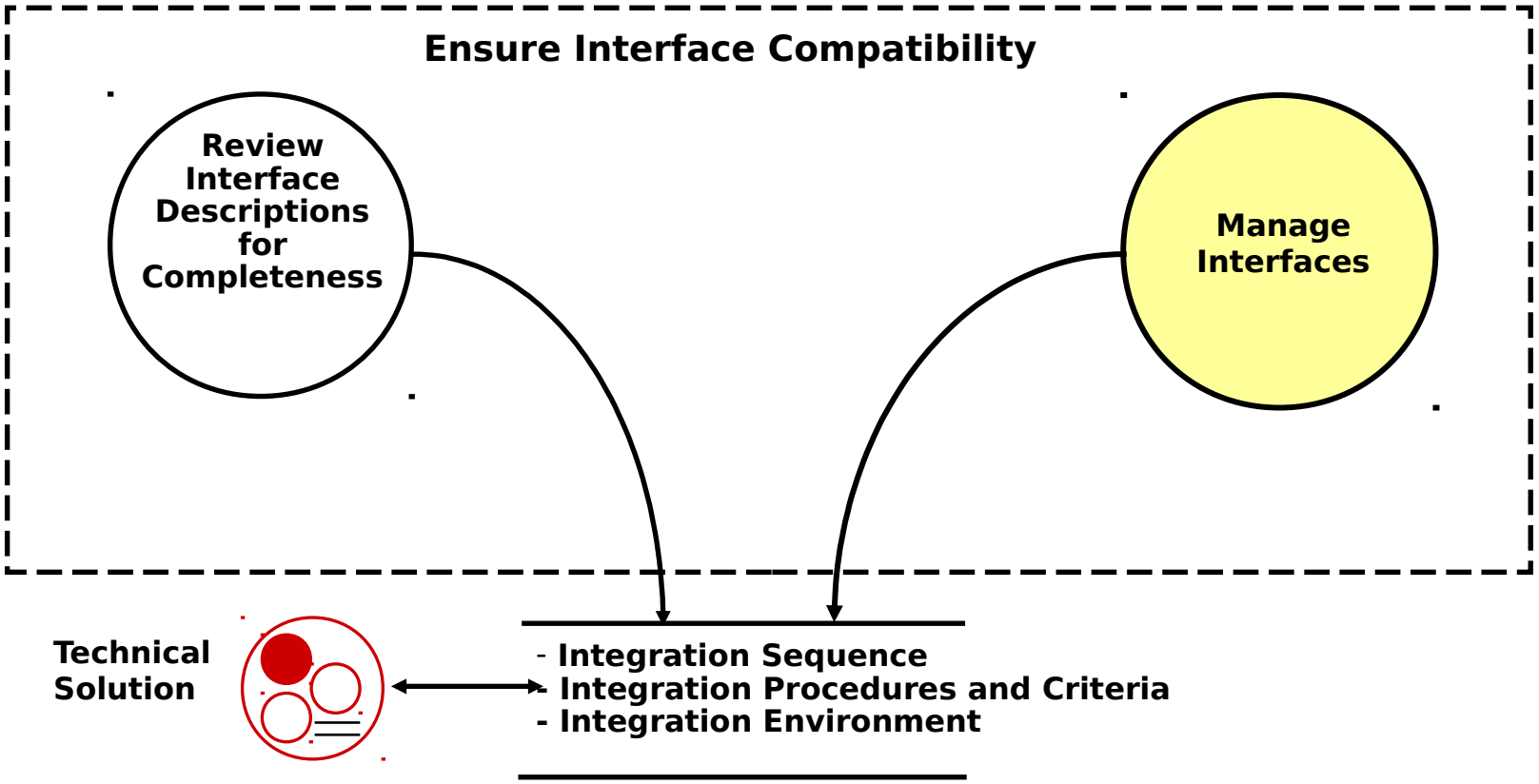
Source: CMMI® -SE/SW/IPPD/SS, V1.1, Continuous Representation, © CMU SEI,2002

PI – Ensuring Interface Compatibility



Source: Introduction to CMMI-Continuous V 1.1 © 2002-2003 by Carnegie Mellon University

PI – Managing Interfaces



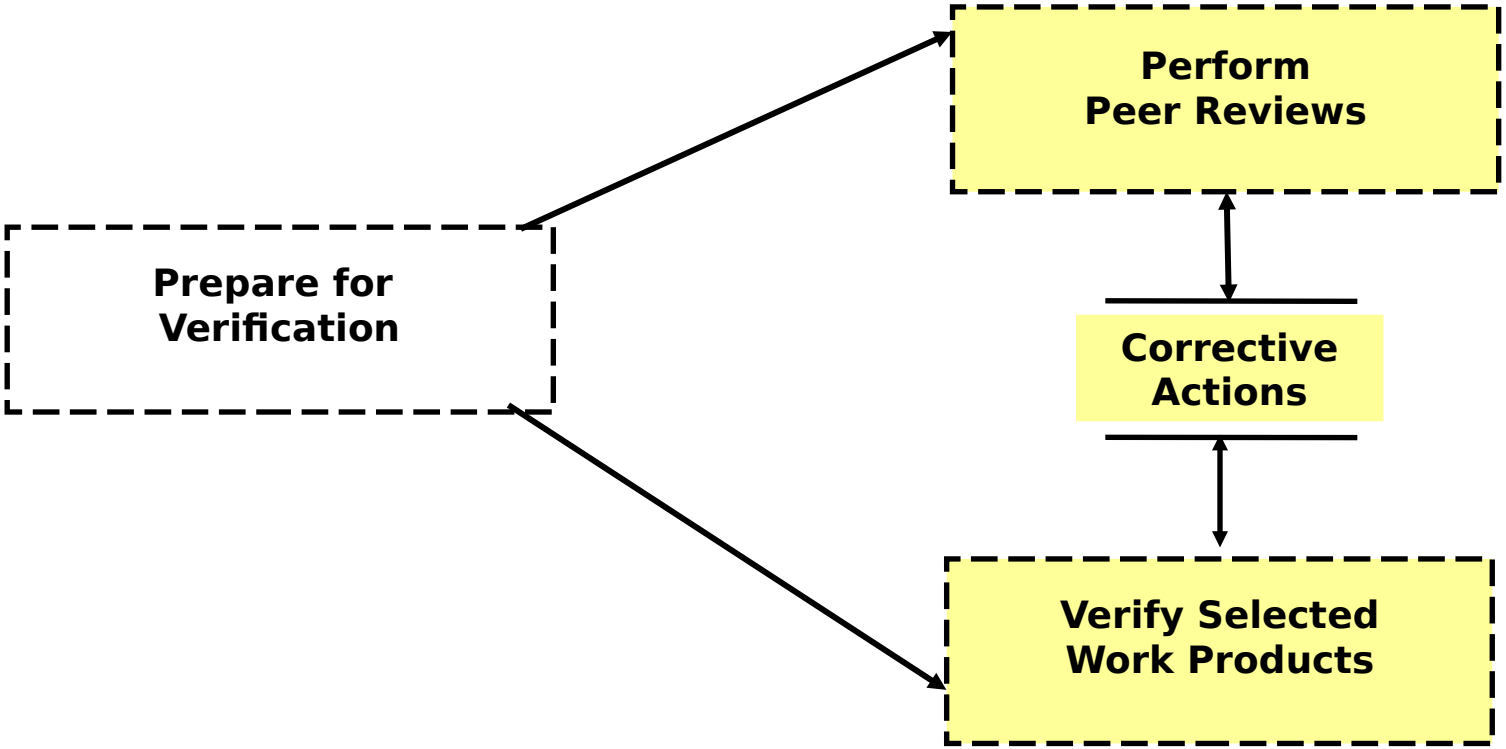
Source: Introduction to CMMI-Continuous V 1.1 © 2002-2003 by Carnegie Mellon University

Verification

- SP 1.1-1 Select Work Products for Verification
  - Select the work products to be verified and the verification methods that will be used for each.
    - Work products are selected based on their contribution to meeting project objectives and requirements, and to addressing project risks.
    - The work products to be verified may include those associated with ***maintenance***, training, and support services. The work product requirements for verification are included with the verification methods. The verification methods address the technical approach to work product verification and the specific approaches that will be used to verify that specific work products meet their requirements.

Source: CMMI® -SE/SW/IPPD/SS, V1.1, Continuous Representation, © CMU SEI,2002

VER – Reporting Corrective Actions



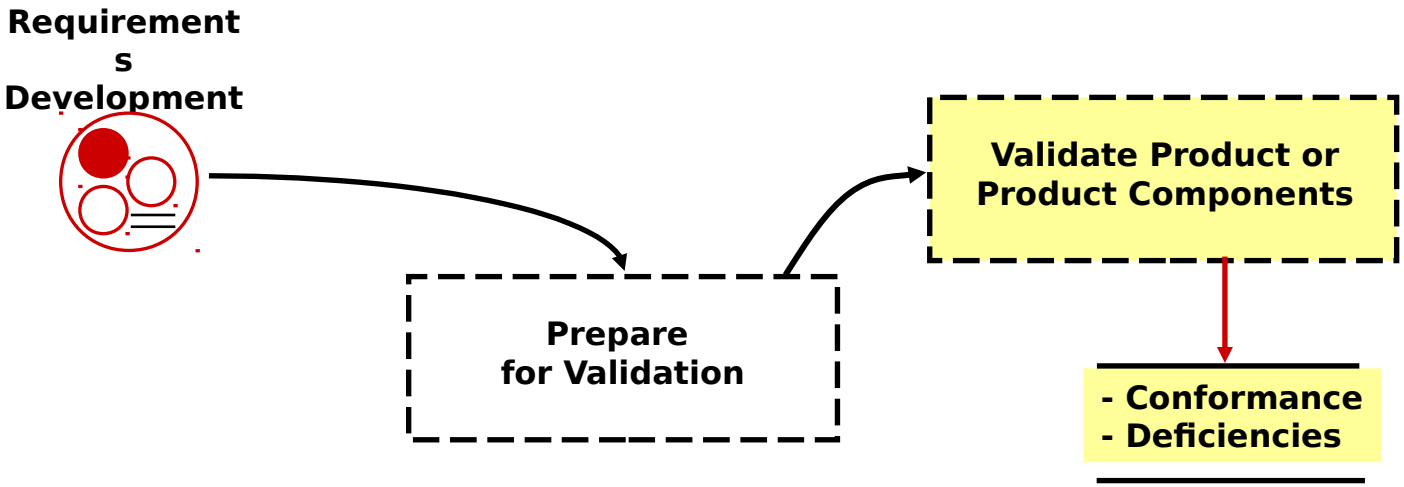
Source: Introduction to CMMI-Continuous V 1.1 © 2002-2003 by Carnegie Mellon University

Validation

- SP 1.1-1 Select Products for Validation
  - *Select products and product components to be validated and the validation methods that will be used for each.*
    - Subpractices
      - 2. Determine which categories of user needs (operational, ***maintenance***, training, or support) are to be validated.
        - The product or product component must be maintainable and supportable in its intended operational environment. This specific practice ***also addresses the actual maintenance, training, and support services that may be delivered along with the product.***

Source: CMMI® -SE/SW/IPPD/SS, V1.1, Continuous Representation, © CMU SEI,2002

VAL – Reporting Conformance Deficiencies



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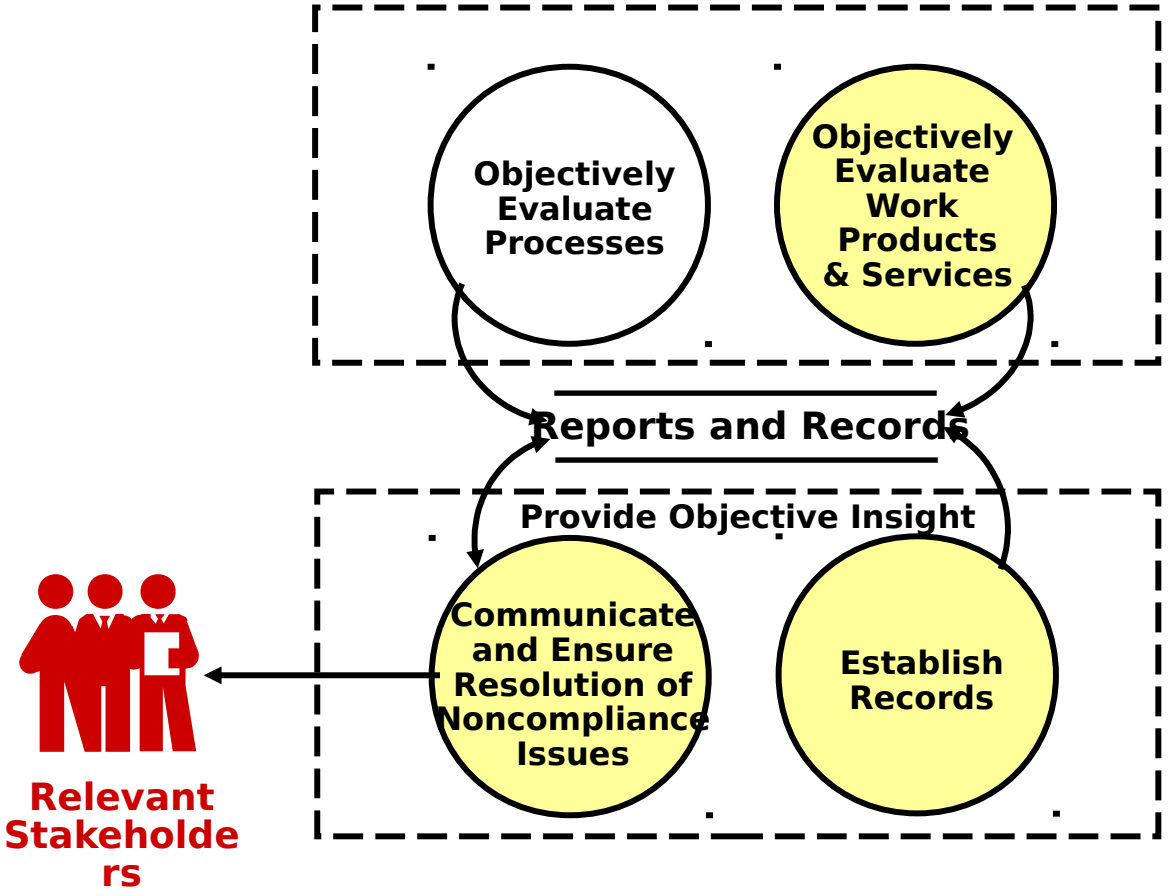
PPQA



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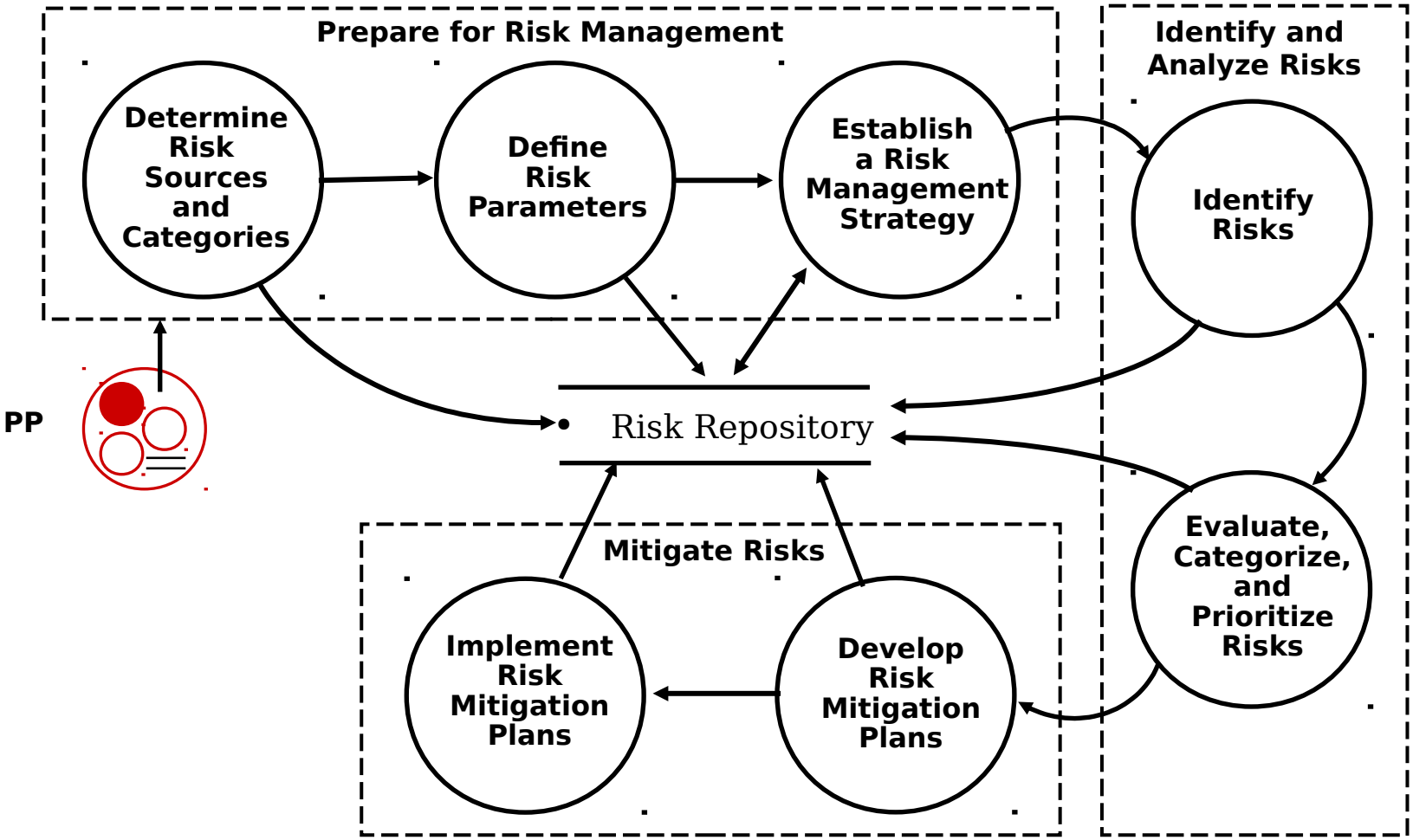
RSKM



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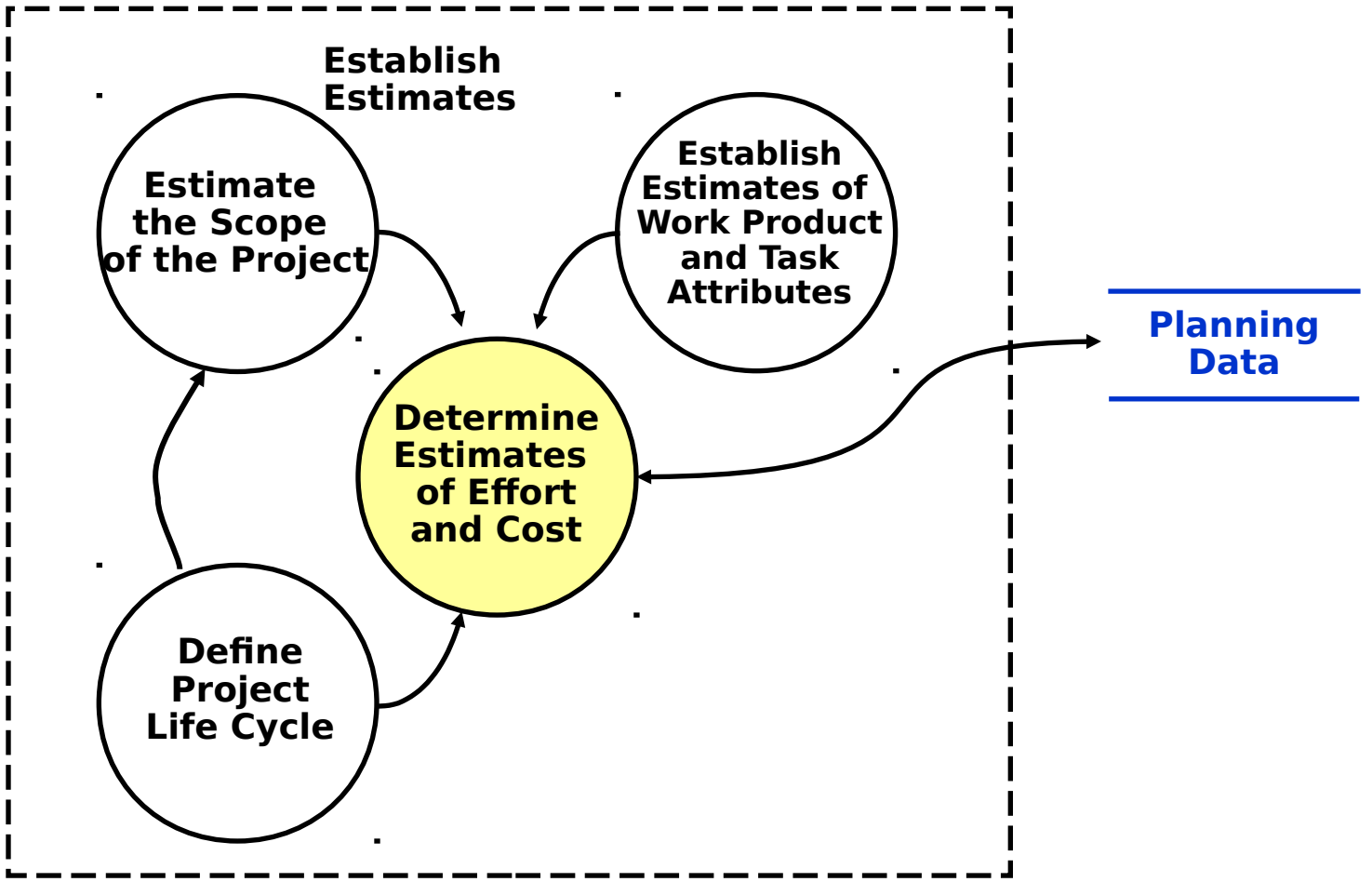
Some Final Issues for Software Maintenance Organizations

Software Maintenance is Different Than Software Development

- Establish the maintenance process
  - Develop maintenance plans and procedures
  - Establish MR/PR procedures
  - Implement configuration management
- Perform problem/modification analysis
  - Analyse MRs/PRs
  - Replicate or verify the problem
  - Develop options for implementing the modification
  - Document the MR/PR, the results, and implementation options
  - Obtain approval for the selected modification option
- Develop and test the modification
- Verify and validate the modification

Source: ISO/IEC 14764:1999, © ISO/IEC1999.

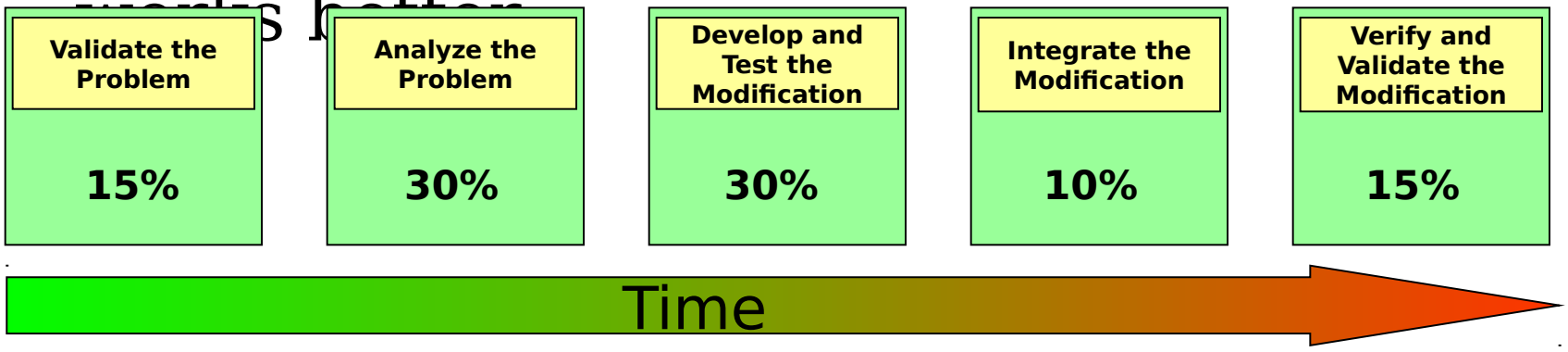
PP – Establish Estimates


Establish Estimates
Estimate the Scope of the Project
Establish Estimates of Work Product and Task Attributes
Determine Estimates of Effort and Cost
Define Project Life Cycle
Planning Data

Source: Introduction to CMMI-Continuous V 1.1 © 2002-2003 by Carnegie Mellon University

An Estimation Conundrum

- Traditional parametric estimation models don't do a very good job of estimating for software maintenance
- A staged, earned-value approach to estimation, based on historical data works better



Note: All values are notional

So You Want to be a CMMI® Level *X*

- For Maintenance Organizations focusing on corrective, preventive, or emergency maintenance
  - Sufficient objective evidence to meet SCAMPI® requirements for a maturity rating may be difficult to obtain
    - Requirements Development may be missing
    - Requirements Management may be weak

For More Information . . .

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For IEEE Standards:

http://computer.org/standards/sesc/

http://computer.org/cspress/CATALOG/st01110.htm

For ISO/IEC Standards:

http://saturne.info.uqam.ca/Labo_Recherche/Lrgl/sc7/

References

CMMI® -SE/SW/IPPD/SS, V1.1, *CMMI for Systems Engineering/Software Engineering/Integrated Product and Process Development, and Supplier Sourcing Version 1.1, CMMI® -SE/SW/IPPD/SS, V1.1, Continuous Representation.* CMU/SEI-CMU/SEI-2002-TR-011, ESC-TR-2002-011, Carnegie Mellon University, Software Engineering Institute, Pittsburgh, PA, March 2002.

IEEE/EIA Standard 12207.0-1996, *Industry Implementation of International Standard ISO/IEC12207:1995 — (ISO/IEC 12207) Standard for Information Technology —Software life cycle processes,* Institute of Electrical and Electronics Engineers, Inc. New York, NY, 1998.

Introduction to CMMI – *Continuous V 1.1*, Carnegie Mellon University, 2002-2003

References - 2

ISO/IEC 14764-1999, *Software Engineering — Software Maintenance*, ISO/IEC JTC1/SC7, 1999.

ISO/IEC 15288:2002, *Systems Engineering — System Life Cycle Processes*, ISO/IEC JTC1/SC7, 2002.

[Singh97] Raghu Singh, *An Introduction to International Standards ISO/IEC 12207, Software Life Cycle Processes*, 1997.